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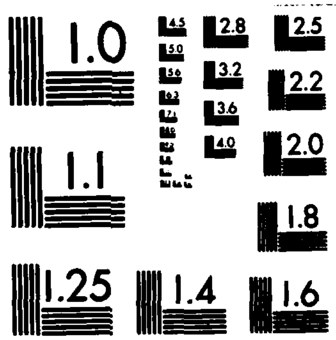

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Structures Technical Memorandum 389

DESCRIPTION AND ILLUSTRATION OF THE USE OF CRACKS IV

by

C. S. DENTRY

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DESCRIPTION AND ILLUSTRATION OF THE USE OF CRACKS IV

by

C. S. DENTRY

Summary

This Memorandum provides an explanation of the procedure required to implement the computer program CRACKS IV for the calculation of crack growth. The procedure is illustrated by means of sample calculations.

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CONTENTS

1. INTRODUCTION

CRACKS IV is a highly versatile computer program for the calculation of crack growth rates using data on material properties, load sequence and crack geometry. Details of the derivation of the formulae used in the program have been given previously[1,2], along with instructions on the use of the program[3].

This Memorandum is directed towards an explanation of the procedure required to implement CRACKS IV to convert flight load data input to an output in terms of crack growth. The procedure will be illustrated by means of a sample calculation of the crack growth rate in a critical area of fuselage frame 26 of the Mirage IIIO aircraft (Appendix 1). Details of the aircraft, the geometry of the fuselage frame and the requirement for the crack growth rate analysis are given elsewhere[4].

2. CRACK GROWTH MODELLING

The essence of a crack growth program is to calculate the change in crack length resulting from the application of a single load cycle to a sample with an existing crack. The calculation is made repetitively for sequential load cycles to determine the time taken for the crack to grow between designated lengths.

The basic materials data used for the calculations are generally documented in the form of a da/dN - ΔK relationship (see also Section 3). In order to calculate the increment of crack growth per load cycle, the value of the stress intensity factor (ΔK) must be determined. This factor requires a knowledge of the crack length, component and crack geometry, and the magnitude of the load cycle as indicated in equation [1].

$$\Delta K = \Delta\sigma \sqrt{\pi a} \times \beta \qquad [1]$$

where ΔK = range of stress intensity factor

$\Delta\sigma$ = cyclic stress range

a = crack length

β = geometrical factor

The above procedure takes no account of the effect on subsequent crack growth of large stress cycles which may produce a retardation of crack growth rate. This retardation effect can be incorporated into the calculation in a number of ways as will be described in Section 3.

3. INPUT DATA REQUIRED FOR CRACKS IV

There are four basic components of the input data required to service CRACKS IV. These are:

3.1 Material Data

The material properties required by CRACKS IV are the yield stress, σ_y, the fracture toughness, K_c, and the rate of crack growth as a function of stress intensity. A typical form of the latter relationship is shown in Figure 1. These data can be used in the program with a variety of formats, described below, which arise from alternative descriptions of the relationship. If raw material data are available it may be more convenient to enter the data in tabulated form.

(a) Paris equation[5]

This equation has the form

$$\frac{da}{dN} = C_o(\Delta K)^{n_o} \qquad [2]$$

specification of the parameters C_o and n_o being required by CRACKS IV. These parameters are sometimes quoted in materials data books.

(b) <u>Walker model</u>[6]

Walker's equation in original form was an extension of the Paris equation to include the influence of the stress ratio, R, i.e.

$$\frac{da}{dN} = C(1 - R)^{m} K_{max}^{n} \qquad [3]$$

However CRACKS IV uses the following equation

$$\frac{da}{dN} = C_1 \left[\frac{\Delta K}{(1-R)^{(1-m_1)}} \right]^{n_1} \qquad [4]$$

The three parameters C_1, m_1 and n_1 are the required input to the program.

(c) <u>Forman equation</u>[7]

The Forman equation has the form

$$\frac{da}{dN} = \frac{C_2(\Delta K)^{n_2}}{(1-R)K_c - \Delta K} \qquad [5]$$

which takes into account the influence of the stress ratio R and the fracture toughness K_c. The two parameters C_2 and n_2 and the material fracture toughness K_c may be found in materials data books.

(d) <u>Tabulated data</u>

The most convenient form of input of constant load amplitude da/dN - ΔK data is tabulated values. A maximum of 10 tables of da/dN - ΔK values, each appropriate to a specific R value, can be accepted by CRACKS IV. The program has the capacity to carry out a two dimensional interpolation/extrapolation on the log-linear plot of da/dN - ΔK, and between the various R values. The influence of extrapolation on crack growth prediction has been investigated in an earlier study[8].

Tabulated values are normally obtained as the output of analysis of the experimental values of constant load amplitude crack growth data (a-N) by an ARL computer program entitled "DADN". This program is based on the ASTM Standard E647[21] which recommends a seven-point incremental polynomial method. It should be noted that this method of analysis provides averaging which results in a loss of data range, i.e. if twenty a-N data values are entered in "DADN", then fourteen da/dN - ΔK values only are determined.

3.2 Load Sequence

The load sequence is commonly described in terms of either turning point data or a range-pair table (RPT). The former retains all sequence information but the RPT loses some of this information by virtue of the intervals over which the data are collected. Typically AFDAS (Aircraft Fatigue Data Analysis System), the source of much of the RPT data, is read after each flight.

If the load sequence is available as a series of turning points, it is used most simply in blocks (e.g. flights) of either max-min or mean-amplitude load cycles. Such a procedure is computationally inefficient in that it requires both large core storage and CPU time. The first level of reduction of core storage/CPU time is to edit out all cycles which will not contribute signficant crack growth. This method of truncation has been discussed in Reference 8. Programs EDIT1 and EDIT2 have been developed to generate edited tabulations of data appropriate for input to CRACKS IV and CRACKS V (see below) respectively.

The orginal version of CRACKS IV stored the entire sequence in two dimensional arrays in the central memory of the computer. However for long sequences, even after editing out the smaller load cycles, the computer central memory may still not have

sufficient capacity to store all turning points. The author therefore modified CRACKS IV (renamed CRACKS V) to allow segments of the sequence to be read consecutively. This results in a small increase in CPU time since all load data must now be read a number of times rather than only once as in the original version. The data re-reads arise from the repetitive application of the flight sequence until the final crack length is reached. The increase in CPU time may be offset by the reduction in required core storage since only a small segment of the total flight sequence now needs to be stored at any one time.

If the data are only available in RPT format, then some sequence information has already been lost. If the RPT summation is over a single flight then the loss of sequence information is believed to be of little consequence[9]. However the gain in speed of analysis may be considerable. Large summation periods (e.g. 500 flights) may offer greater gains in computational efficiency, but this is balanced by some reduction in the accuracy of the crack growth prediction due to the loss of sequence information. Such sequence information is essential for the calculation of the retardation effect of high loads. Balancing these two effects (computational efficiency/accuracy) requires judgement on the part of the user of CRACKS IV.

All load information must be entered into CRACKS IV in the form of stresses. The ARL version of the program includes a multiplier on stresses enabling the entire sequence to be factored if required. The method of incorporating this factor is illustrated in the example given in Appendix 1.

3.3 Geometric Factors

CRACKS IV as originally developed provided for five different crack geometries. These are:

(a) a through crack in a plate with a finite width correction developed by Fedderson[10] to allow for the non-infinite specimen width;

(b) a single through crack initiating from a hole in a plate, developed by Bowie[11];

(c) as (b) for a double through crack;

(d) ASTM compact tension specimen;

(e) Grumman compact tension specimen.

In addition CRACKS IV will accept a constant value of β, or tabulated values of β as a function of crack length a.

The author has developed a further option which allows the insertion of an equation not included in the above, e.g. the Liu solution for a corner crack[12].

In order to make accurate crack growth predictions for aircraft structures, suitable stress intensity models are required. The above models are generally adequate for simple laboratory specimens, e.g. Fedderson's model has proven successful in defining the influence of geometry on the stress intensity of centre crack tension specimens; for compact tension specimens, both the ASTM and Grumman models can be used with confidence for the appropriate specimens. However these models cannot be justified for many of the complex crack geometries found in aircraft structures. For such situations finite element analysis could be carried out to define the influence of the crack geometry. Nevertheless this is inefficient and unnecessary when one considers the extensive literature available from studies of stress intensity factors and the influence of different crack geometries. While it is often difficult to find a solution already formulated for the geometry under consideration, a process of superposition can usually be applied. This enables the stress intensity of a complex geometry to be built up of a number of simpler models, e.g. the Bowie solution can be thought of as the superposition

of a stress intensity solution of a through crack upon the stress field from a hole. The solution of an embedded crack emanating from a hole has been developed using the above process and is described in Appendix 2.

The transition from one crack geometry to another must be formulated. The author has chosen to employ a method which follows a constant β value which passes through the crack length equidistant from the two endpoints. This may be illustrated by reference to Figure 2 for the transition from a corner crack to a through crack emanating from a hole, i.e. a transition from the Liu solution (corner crack) to the Bowie solution (through crack). When the crack length, a, has a value equal to the material thickness t, it is assumed that the crack geometry factor has a value midway between the Bowie and Liu solutions (point E). The transition between the two solutions is along a line of constant β passing through point E. In order to follow this process, CRACKS IV is commanded to use the Liu solution for crack lengths less than a_B, to use a crack geometry factor β_E for crack lengths from a_B to a_D and to follow Bowie thereafter.

3.4 Retardation Models

CRACKS IV contains four retardation models which have been proposed to take account of the reduction of crack growth rate occurring after the application of a high load (commonly referred to as an overload). The theories behind these models can be found in references 1, 2 and 8. These models are:

(a) Wheeler[13]
This model introduces a retardation parameter C_p which factors the crack growth rate as described by the relationship

$$a_n = a_o + \sum_{i=1}^{n} C_{pi} F(\Delta K_i) \qquad [6]$$

where

$$C_{pi} = \left(\frac{R_y}{a_\rho - a}\right)^m \; ; \; (a + R_y < a_p)$$

R_y = extent of current yield zone

$a_\rho - a$ = distance between crack tip and the longest elastic-plastic interface caused by prior cycling

m = a shaping parameter which must be determined experimentally or obtained from data handbooks.

It has been suggested[13] that m is material dependent, although other authors[8,14] have reported that m also has load dependence. The value of R_y is a function of whether the component is in a state of plane stress or plane strain. Reference 15 documents a technique which evaluates the stress state appropriate to any given geometry.

(b) Willenborg[16]

Willenborg effected retardation by reducing both the maximum and minimum stress values of cycles following an overload. The amount these stresses are reduced is expressed as

$$\sigma_{red} = \frac{\sigma_y}{\beta} \sqrt{\frac{2(a_\rho - a)}{a}} - \sigma_2 \qquad [7]$$

where

σ_y = yield stress of material

β = geometric factor as described previously

σ_2 = maximum value of current stress cycle.

The above stress reductions have the effect of:

(i) reducing the stress ratio R leaving ΔK unchanged; or

(ii) reducing ΔK for $R = 0$; or

(iii) making ΔK and R both equal zero when $\sigma_{2(max)} < \sigma_{red}$

This model in its standard form requires no additional input parameters.

(c) Willenborg modified[17]

The Willenborg model in its standard form implies that for an overload ratio (Figure 3) $\frac{\sigma_1}{\sigma_2} \geq 2$, no crack growth will occur. Experimental data have shown crack growth continuing for overload ratios in excess of 2.5[18]. To overcome this contradiction, Gallagher and Hughes[17] modified the Willenborg model by introducing the parameter

$$\phi = \frac{\sigma_{red}}{\sigma_{red}} \quad \text{(due to Willenborg)} \qquad [8]$$

where ϕ accounts for the effect of the overload ratic just producing crack arrest (S), and K_{th} (K_{th} is the threshold value of the stress intensity for crack growth). The parameter S has been found[8] to be both material and load dependent and as a consequence it cannot be expected that, in general, the standard version of Willenborg will be capable of accurate crack growth prediction. It must be noted that both of the Willenborg models can only be used with da/dN - ΔK data which incorporate the influence of the stress ratio R.

(d) Grumman crack closure model[19,20]

This model introduces the concept of an effective stress range, i.e. the difference between the maximum stress and that corresponding to the crack closure/opening stress (σ_c). Defining a closure factor (C_f) as

$$C_f = \sigma_c/\sigma_{max} \qquad [9]$$

the stress ratio effect is modelled by

$$C_f = C_{f_{-I}} + (C_{f_0} - C_{f_{-1}})(1 + R)^p \qquad [10]$$

and C_{f_0}, $C_{f_{-1}}$ and p are constants.

The above equation only applies for crack growth under stabilised conditions, i.e. no retardation. In order to take retardation into account, the closure stress is modified as indicated in the equation

$$\sigma_c = \sigma_{c1} - (\sigma_{c1} - \sigma_{c2})\left(\frac{a_p - a}{R_y}\right)^b \qquad [11]$$

where

R_y = overload plastic zone radius
b = 1.0 for both aluminium and titanium
σ_{c1} = stabilized closure stress for overload stress σ_1
σ_{c2} = stabilized closure stress for stress σ_2

This model also takes account of the effect of multiple overloads by means of the equation

$$\gamma = \gamma_1 + (1 - \gamma_1)\left(\frac{N_{o\ell} - 1}{N_{sat} - 1}\right) \qquad [12]$$

where γ = the ratio of the closure stress after the application of a number of overloads ($N_{o\ell}$) to the stabilised overload closure stress.

γ_1 = the value of γ for $N_{o\ell} = 1$

N_{sat} = the number of overloads beyond which further overloads produce no increase in retardation.

The Grumman model was found to have similar problems to the Wheeler and Willenborg models in that the parameters were load as well as material dependent.

It was necessary to substantially modify the original version of the crack closure model in CRACKS IV in order for it to utilize varying amplitude cycle-by-cycle load data. This ARL-modified version of CRACKS IV has been designated CRACKS IVM.

The crack closure model requires that the constant amplitude da/dN - ΔK material data be relevant to a stress ratio R = 0. Consequently, if the constants C_{f_0}, $C_{f_{-1}}$, P are known for the material of interest, only the Paris constants for a single tabulation of da/dN - ΔK are required.

4. CONCLUSIONS AND RECOMMENDATIONS

Of all descriptive forms of the material da/dN - ΔK data, the most convenient was found to be the tabulated data. Efficient generation of the above data is best achieved by converting raw a - N data to da/dN - ΔK by means of the ASTM seven point incremental polynomial technique.

The use of varying amplitude cycle-by-cycle load sequence data generally requires some form of editing in order to keep computational costs to a reasonable value.

A study by the author has evaluated the Bowie solution for through cracks and the Liu formulation for corner cracks emanating from holes and has found both of them to be satisfactory. If solutions are required for crack geometries such as lugs it is recommended that Newman's[22] solution be employed.

None of the retardation models in CRACKS IV were found to be satisfactory in their original form. The Wheeler, Willenborg modified and Grumman models could be forced to provide crack growth estimates close to experimentally determined values if parameters appropriate to each model were made dependent on material properties and the maximum stress within the load sequence. This parameter dependence cannot be easily obtained for either the Willenborg modified or the Grumman model because of a limited data base for these models. On the other hand, the Wheeler model has been used so extensively that published data, from which the parameter dependence can be obtained, are readily available. It is therefore recommended that the Wheeler model be used whenever possible.

Crack growth rate is so highly dependent on stress level that significant errors can be introduced by small stress uncertainties. Typically a 10% change in applied stress may produce a 50% difference in crack growth rate[8]. In a practical aircraft structure considerable effort will often be necessary to determine the stress levels with sufficient accuracy to ensure that the crack growth rate estimation is meaningful.

5. ACKNOWLEDGEMENT

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APPENDIX 1

PROBLEM 1: CRACK GROWTH PREDICTION FOR CALIBRATING WHEELER PARAMETER m

The example below is used to illustrate the input parameters and output data of CRACKS IV for a typical calculation. The calculation was conducted in order to calibrate the Wheeler retardation parameter m against experimental data. A centre-cracked tension specimen (20 x 100 mm in section) was made of A7-U4SG-T651 aluminium alloy with an initial half-crack length of 10.42 mm. This specimen was loaded under a cycle-by-cycle sequence consisting of 24 basic flights arranged in a specified manner to produce a 200 flight sequence. The maximum load in the sequence was 134 MPa. EDIT1 was used to edit the sequence suppressing all maximum loads below 27 MPa. The constant amplitude da/dN - ΔK material data as illustrated in Tables 1, 2 and 3 were derived from experimental data produced at ARL and processed through the program DADN as described in Section 3.1.

The threshold stress intensity value was specified as

$$\Delta K_{th} = (2.1 \times 10^{6})(1 - R) \quad \mathrm{MPa}\sqrt{m}$$

The following values were specified as input to CRACKS IV: viz

$$K_c = 48.6 \ \mathrm{MPa}\sqrt{m}$$

$$\sigma_y = 458 \ \mathrm{MPa}$$

A final half-crack length was specified as 49 mm. The input file is documented in part in Table 4. The output file is given in Table 5.

PROBLEM 2: PREDICTION OF CRACK GROWTH FOR HOLE IN MIRAGE FUSELAGE FRAME 26

In this problem a comparison was made between theoretical calculations of crack growth from CRACKS IV with experimental results from a specimen simulating a section of the bottom of the Mirage fuselage frame 26. The area of interest had a material thickness of 8 mm and hole diameter of 6 mm. An initial crack depth of 0.36 mm was assumed. A Wheeler retardation parameter of 4.2 was applied using the method outlined in Section 3.4 with the curves of Reference 14. The geometry assumed was initially an embedded crack; a description of the stress intensity for such a crack is given in Appendix 2. The method of incorporating the transition from embedded to through crack is that as described in Section 3.3, although in this case the crack was initially embedded.

As stated in Appendix 2, c/a is assumed to be 1.50 for embedded cracks. Consequently for $t = 8$ mm

$d = 6$ mm

and taking $2a/t = 1.0$ as the dimensions of the crack where its shape may be considered as either embedded or through, it follows that $c = 4$ mm and $a = 2.67$ mm. This implies $a/d = 0.44$ giving $\beta = 1.44$ from Figure 4. It can also be seen from Figure 4, that the crack remains embedded from the initial crack size until $a = 2.1$ mm, it has a constant β value of 1.44 until $a = 3.36$ mm, whereafter it continues as a through crack.

The material and load sequence was as described in Problem 1. The maximum stress however had been increased to 330 MPa. The input file for CRACKS IV is documented in part in Table 6. The output file is given in Table 7. A comparison of the experimental and calculated crack growth is shown in Figure 5.

SOLUTION FOR THE STRESS INTENSITY OF AN EMBEDDED CRACK EMANATING FROM A HOLE

Reference 15 recommends the following formula for the modelling of a symmetric embedded crack emanating from a hole:

$$\text{Stress intensity } K = M_f(c/a) \times M_b(c/a, a/t, \theta) \times M_{2h}(\tfrac{a}{d}, \theta) K_{Ie}$$

where

	M_f	=	front face surface correction
		=	$1 + 0.12(1 - a/2c)^2$
	M_b	=	back face correction
		=	1.0 for $2c/t < 0.5$
	M_{2h}	=	stress field correction
	K_{Ie}	=	the stress intensity for an embedded crack and is given by the following equations.

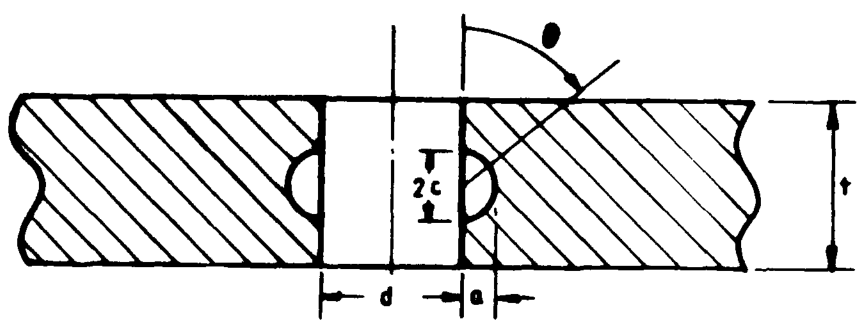
For $c/a \leq 1.0$

$$K_{Ie} = \sigma\sqrt{\pi c} \times \frac{1}{\sqrt{Q}} \left[\cos^2\theta + \left(\frac{c}{a}\right)^2 \sin^2\theta\right]^{\frac{1}{4}}$$

$c/a > 1.0$

$$K_{Ie} = \sigma\sqrt{\pi a} \times \frac{1}{\sqrt{Q}} \left[\sin^2\theta + \left(\frac{a}{c}\right)^2 \cos^2\theta\right]^{\frac{1}{4}}$$

Q = shape factor (Figure 6)



The variations of stress intensity around the crack front were evaluated for various values of c/a. Table 8 shows values of the non-dimensional stress intensity as a function of θ for various values of c/a. The variation of the stress intensity with θ is smallest for

c/a = 1.50. It is therefore assumed that embedded cracks will stabilise at this value of c/a. This occurs because a crack with a large difference in stress intensity as a function of θ will continue to change shape as the crack preferentially grows in the region of highest stress intensity. An experimental confirmation of this is illustrated in Figure 7.

If the value of the stress intensity is assumed to be independent of θ for c/a = 1.50 then

$$Q = 1.60$$
$$K_{Ie} = \sigma\sqrt{\pi a} \times 0.790$$

Furthermore, the following equation can be derived from figures supplied in reference 15.

$$M_{2h} = \left[\frac{0.262}{0.1708+a/d} + 1.36\right] \quad \text{for } a/d \leq 0.15$$
$$= \left[\frac{0.3433}{0.1386+a/d} + 0.9439\right] \quad \text{for } a/d > 0.15$$

consequently

$$K = K_{Ie} \times M_{2h} \times M_b \times M_f$$
$$= \Delta\sigma\sqrt{\pi a} \times \left[\frac{0.218}{0.1708+a/d} + 1.132\right] \quad \text{for } a/d \leq 0.15$$
$$= \Delta\sigma\sqrt{\pi a}\left[\frac{0.2857}{0.1153+a/d} + 0.7853\right] \quad \text{for } \frac{a}{d} > 0.15$$

TABLE 1. CONSTANT AMPLITUDE $\frac{da}{dN}$ - ΔK MATERIAL DATA*, R = 0
(A7-U4SG-T651)

```
0.0
34
    3411266.       0.2529789E-08
    3788746.       0.3032713E-08
    3842476.       0.3173423E-08
    5756974.       0.7263639E-08
    6001927.       0.8250527E-08
    6134541.       0.8875001E-08
    6290292.       0.9916666E-08
    6371183.       0.1050000E-07
    6455282.       0.1117937E-07
    6644311.       0.1296602E-07
    6830418.       0.1535339E-07
    7107603.       0.1898393E-07
    7609374.       0.2849419E-07
    8963895.       0.6970323E-07
    9638227.       0.1031339E-06
   0.1199231E+08   0.2059717E-06
   0.1278307E+08   0.2649429E-06
   0.1342312E+08   0.3174021E-06
   0.1457318E+08   0.4253397E-06
   0.1595467E+08   0.5203570E-06
   0.1641250E+08   0.5596428E-06
   0.2007755E+08   0.9487257E-06
   0.2049340E+08   0.1097834E-05
   0.2098839E+08   0.1254679E-05
   0.2161195E+08   0.1452330E-05
   0.2245008E+08   0.1704576E-05
   0.2351969E+08   0.2012259E-05
   0.2413143E+08   0.2266666E-05
   0.2490697E+08   0.2816609E-05
27.27273E6  0.619E-5
31.81818E6  0.3677701E-4
36.36364E6  0.3501728E-3
40.90909E6  0.5049506E-2
45.45455E6  0.1036146
```

* Input file as required by CRACKS IV for tabulated material data.

First line	R
Second line	No. of lines of data values
Third and subsequent lines	Pairs of $\Delta K(Pa\sqrt{m})$ and $\frac{da}{dN}$ (m cycle^{-1}) values

TABLE 2. CONSTANT AMPLITUDE da/dN - ΔK MATERIAL DATA, R = 0.2 (A7-U4SG-T651)

0.2
37

2808717.	0.1706983E-08
2837185.	0.1788651E-08
2932283.	0.2061685E-08
3003399.	0.2161899E-08
3076432.	0.2270229E-08
3236970.	0.2508910E-08
5142188.	0.7383497E-08
5418546.	0.8114286E-08
5467171.	0.8578571E-08
5639517.	0.9785714E-08
5888241.	0.1050714E-07
5949979.	0.1110714E-07
6167458.	0.1402857E-07
6453030.	0.1674750E-07
6552214.	0.1814999E-07
6773514.	0.2257448E-07
7054406.	0.2688851E-07
7280166.	0.3253410E-07
7900266.	0.5058482E-07
8374838.	0.6901570E-07
9080572.	0.9298651E-07
9529765.	0.1222809E-06
0.1160082E+08	0.2342857E-06
0.1280948E+08	0.3224219E-06
0.1349662E+08	0.4060715E-06
0.1427173E+08	0.4907144E-06
0.1544440E+08	0.6674244E-06
0.1754811E+08	0.9700278E-06
0.1793710E+08	0.1043132E-05
0.1834195E+08	0.1097024E-05
0.1934058E+08	0.1440078E-05
20.03205E6	0.1695190E-5
24.03846E6	0.619E-5
28.04487E6	0.36777E-4
32.05128E6	0.350172E-3
36.05769E6	0.5049506E-2
40.06410E6	0.1036146

TABLE 3. CONSTANT AMPLITUDE da/dN - ΔK MATERIAL DATA, R = 0.7 (A7-U4SG-T651)

0.6999531	
27.00000	
2365061.	0.1978670E-08
2428595.	0.2160712E-08
2494953.	0.2289286E-08
4176679.	0.8707143E-08
4337826.	0.1099286E-07
4680269.	0.1592857E-07
4850378.	0.1826745E-07
5028986.	0.2107912E-07
5210989.	0.2483928E-07
5435592.	0.3005128E-07
5714171.	0.3583769E-07
6051183.	0.4607704E-07
6272433.	0.5432908E-07
6698376.	0.7653572E-07
7671962.	0.1473751E-06
8037057.	0.1752877E-06
9092664.	0.3074945E-06
9621431.	0.4123801E-06
9982782.	0.5082955E-06
0.1047012E+08	0.6945087E-06
0.1130393E+08	0.1293509E-05
12100000	0.1695190E-5
14500000	0.6190034E-5
16900000	0.3677701E-4
19800000	0.3501728E-3
22700000	0.5049506E-2
25000000	0.1036146

TABLE 4. INPUT FILE FOR CRACKS IV FOR PROBLEM 1. FOR KEYWORD DEFINITION. SEE REFERENCE 3.

```
  TITLE
  1
  SPECIMEN 20 MM THICK CCT 17.98 MPA/G
  EQUATION
  R-DA/DN
  MATERIAL
  ALUMINIUM ALLOY
  48.6E6 458.0E6
  THRESHOLD
  2.1E6 1.0
  LIMITS
  0.01042 0.0 0.0 1.00
  ANALYSIS
  RETARD     1 0 1.50 1 0
  BETA     2 0.100 0.01042 0.050
  END
  LOADS
  110 1          SWISS SEQUENCES SPECIMEN (24)
* 1.000
  MAX-MIN
      0.1976700E+08  0.0000000E+00      1
      0.3594000E+08  0.1797000E+08      1
      0.3594000E+08  0.1797000E+08      1
      0.7188000E+08  0.2695500E+08      1
      0.5391000E+08  0.1797000E+08      1
      0.6289500E+08  0.3594000E+08      1
      0.5391000E+08  0.3594000E+08      1
      0.8086500E+08  0.6289500E+08      1
      0.8086500E+08  0.5391000E+08      1
      0.6289500E+08  0.4492500E+08      1
      0.7188000E+08  0.2695500E+08      1
      0.5391000E+08  0.1797000E+08      1
      0.9883500E+08  0.3594000E+08      1
      0.9883500E+08  0.3594000E+08      1
      0.8086500E+08  0.5391000E+08      1
      0.8985000E+08  0.1797000E+08      1
      0.3594000E+08  0.1797000E+08      1
      0.1168050E+09  0.5391000E+08      1
      0.8086500E+08   8985000.          1
      0.4492500E+08  0.1797000E+08      1
      0.1168050E+09  0.1797000E+08      1
      0.3594000E+08 -0.3594000E+08      1
      0.8985000E+08   8985000.          1
      0.5391000E+08  0.1797000E+08      1
      0.1078200E+09  0.2695500E+08      1
      0.5391000E+08  0.2695500E+08      1
      0.8086500E+08  0.2695500E+08      1
      0.8086500E+08  0.3594000E+08      1
      0.1078200E+09  0.1797000E+08      1
      0.6289500E+08  0.1797000E+08      1
      0.9883500E+08   8985000.          1
      0.3594000E+08  0.1797000E+08      1
      0.4492500E+08   8985000.          1
 END
```

* This is the stress multiplier factor.

TABLE 4. CONTINUED

MAX-MIN

0.1976700E+08	0.0000000+00	1
0.3594000E+08	0.1797000E+08	1
0.3594000E+08	0.1797000E+08	1
0.3594000E+08	0.1797000E+08	1
0.7188000E+08	0.2695500E+08	1
0.5391000E+08	0.1797000E+08	1
0.6289500E+08	0.3594000E+08	1
0.5391000E+08	0.3594000E+08	1
0.8086500E+08	0.6289500E+08	1
0.8086500E+08	0.5391000E+08	1
0.6289500E+08	0.44925	
0.5391000E+08	0.1797000E+08	1
0.3594000E+08	0.1797000E+08	1
0.5381000E+08	0.1797000E+08	1
0.6289500E+08	0.3594000E+08	1
0.5391000E+08	0.1797000E+08	1
0.4492500E+08	0.1797000E+08	1
0.3594000E+08	0.1797000E+08	1
0.3594000E+08	0.1797000E+08	1

END

TABLE 5. OUTPUT FROM CRACKS IV FOR PROBLEM 1.

```
CRACKS-IV    VERSION 5, 04/26/79    R.M. ENGLE JR.
ARL ADAPTATION - JANUARY 1980

CASE  1     RUN  1
SWISS SPECIMEN RUN
DIRECT INPUT OF DA/DN VS DELTAK FOR   SEVERAL VALUES OF STRESS RATIO R.
ALUMINIUM ALLOY

KSUBQ = 4.8600E+07      YIELD STRESS = 4.5800E+08

THRESHOLD DELTA K = 2.1000E+06*(1.0- 1.000*R)

INITIAL HALF CRACK LENGTH =  1.0420E-02
INITIAL CYCLE NUMBER =       0.00
R CUTOFF = 0.950
AUTOMATIC UNRETARDED SOLUTION SUPPRESSED
WHEELER'S RETARDATION MODEL WITH SHALLH = 0.750
PLANE STRAIN YIELD ZONE CONDITION ASSUMED
CORRECTION FACTOR BETA(2) IS FINITE WIDTH CORRECTION
    BETA(2) = SQRT(SEC(PI*A/B))
    WHERE THE EFFECTIVE PLATE WIDTH  W = 1.0000E-01
    APPLIED FROM A =  1.0420E-02 TO  A = 4.9000E-02
MULTIPLICATION FACTOR =     1.000000
         SWISS SEQUENCES SPECIMEN (24)

    40 BLOCKS IN SPECTRUM


END OF INPUT
**********CRACKS IV ANALYSIS**********

         SWISS SEQUENCES SPECIMEN (24)

 FLT HSK LYR CYCLES      A      DELTA K    K MAX      DADN     RETARD
   1  14   1  1.0  0.0104  .368E+07  .368E+07  2.872E-09  1.000
   1  14   2  2.0  0.0104  .501E+07  .835E+07  1.069E-08  1.000
   1  14   3  3.0  0.0104  .501E+07  .669E+07  5.484E-09  0.716
   1  14   4  4.0  0.0104  .501E+07  .668E+07  5.486E-09  0.716
   1  14   5  5.0  0.0104  .501E+07  .668E+07  5.487E-09  0.716
   1  14   6  6.0  0.0104  .334E+07  .668E+07  2.607E-09  0.716
   1  14   7  7.0  0.0104  .668E+07  .100E+08  2.917E-08  1.000
   1  14   8  8.0  0.0104  .334E+07  .668E+07  1.981E-09  0.544
   1  14   9  9.0  0.0104  .501E+07  .835E+07  8.133E-09  0.761
END OF SEGMENT   100 OF BLOCK    1      CRACK LENGTH =  1.0564E-02
END OF SEGMENT   200 OF BLOCK    1      CRACK LENGTH =  1.0731E-02
END OF BLOCK     1          CRACK LENGTH =  1.0731E-02
   GROWTH THIS BLOCK =  3.1056E-04      TOTAL GROWTH =  3.1056E-04


END OF SEGMENT   100 OF BLOCK    2      CRACK LENGTH =  1.0920E-02
END OF SEGMENT   200 OF BLOCK    2      CRACK LENGTH =  1.1057E-02
END OF BLOCK     2          CRACK LENGTH =  1.1057E-02
   GROWTH THIS BLOCK =  3.2621E-04      TOTAL GROWTH =  6.3678E-04


END OF SEGMENT   100 OF BLOCK    3      CRACK LENGTH =  1.1216E-02
END OF SEGMENT   200 OF BLOCK    3      CRACK LENGTH =  1.1406E-02
END OF BLOCK     3          CRACK LENGTH =  1.1406E-02
   GROWTH THIS BLOCK =  3.4830E-04      TOTAL GROWTH =  9.855[illegible]


END OF SEGMENT   100 OF BLOCK    4      CRACK LENGTH =  1.157[illegible]
END OF SEGMENT   200 OF BLOCK    4      CRACK LENGTH =  1.1781E-02
END OF BLOCK     4          CRACK LENGTH =  1.1781E-02
   GROWTH THIS BLOCK =  3.7515E-04      TOTAL GROWTH =  1.36[illegible]
```

TABLE 4. CONTINUED

```
END LOADS
SPECTRUM
200 1
1 14
1 10
1 6
1 11
1 15
1 16
1 17
1 21
1 23
1 13
1 11
1 22
1 24
1 5
1 12
1 18
1 14
1 5
1 23
1 13
1 3
1 8
1 21
1 17
1 11
1 13
1 15
1 24
1 21
1 11
1 23
1 22
1 7
1 11
1 22
1 6
1 10
1 14
1 16
1 5
1 14
1 23
1 13
1 23
1 17
1 15
1 14
1 16
PRINT
1 100 0 0 0 1000
END DATA
```

TABLE 5. CONTINUED

```
END OF SEGMENT   100 OF BLOCK    5      CRACK LENGTH =  1.196[illegible]E-02
END OF SEGMENT   200 OF BLOCK    5      CRACK LENGTH =  1.2187E-02
END OF BLOCK    5           CRACK LENGTH =  1.2187E-02
   GROWTH THIS BLOCK =  4.0617E-04     TOTAL GROWTH =  1.7669E-03

END OF SEGMENT   100 OF BLOCK    6      CRACK LENGTH =  1.2388E-02
END OF SEGMENT   200 OF BLOCK    6      CRACK LENGTH =  1.2632E-02
END OF BLOCK    6           CRACK LENGTH =  1.2632E-02
   GROWTH THIS BLOCK =  4.4465E-04     TOTAL GROWTH =  2.2115E-03

END OF SEGMENT   100 OF BLOCK    7      CRACK LENGTH =  1.2855E-02
END OF SEGMENT   200 OF BLOCK    7      CRACK LENGTH =  1.3125E-02
END OF BLOCK    7           CRACK LENGTH =  1.3125E-02
   GROWTH THIS BLOCK =  4.9391E-04     TOTAL GROWTH =  2.7055E-03

END OF SEGMENT   100 OF BLOCK    8      CRACK LENGTH =  1.3375E-02
END OF SEGMENT   200 OF BLOCK    8      CRACK LENGTH =  1.3676E-02
END OF BLOCK    8           CRACK LENGTH =  1.3676E-02
   GROWTH THIS BLOCK =  5.5090E-04     TOTAL GROWTH =  3.2564E-03

END OF SEGMENT   100 OF BLOCK    9      CRACK LENGTH =  1.3954E-02
END OF SEGMENT   200 OF BLOCK    9      CRACK LENGTH =  1.4291E-02
END OF BLOCK    9           CRACK LENGTH =  1.4291E-02
   GROWTH THIS BLOCK =  6.1482E-04     TOTAL GROWTH =  3.8712E-03

END OF SEGMENT   100 OF BLOCK   10      CRACK LENGTH =  1.4604E-02
END OF SEGMENT   200 OF BLOCK   10      CRACK LENGTH =  1.4994E-02
END OF BLOCK   10           CRACK LENGTH =  1.4994E-02
   GROWTH THIS BLOCK =  7.0305E-04     TOTAL GROWTH =  4.5742E-03

END OF SEGMENT   100 OF BLOCK   11      CRACK LENGTH =  1.5360E-02
END OF SEGMENT   200 OF BLOCK   11      CRACK LENGTH =  1.5828E-02
END OF BLOCK   11           CRACK LENGTH =  1.5828E-02
   GROWTH THIS BLOCK =  8.3385E-04     TOTAL GROWTH =  5.4081E-03

END OF SEGMENT   100 OF BLOCK   12      CRACK LENGTH =  1.6271E-02
END OF SEGMENT   200 OF BLOCK   12      CRACK LENGTH =  1.6862E-02
END OF BLOCK   12           CRACK LENGTH =  1.6862E-02
   GROWTH THIS BLOCK =  1.0341E-03     TOTAL GROWTH =  6.4422E-03

END OF SEGMENT   100 OF BLOCK   13      CRACK LENGTH =  1.7434E-02
END OF SEGMENT   200 OF BLOCK   13      CRACK LENGTH =  1.8265E-02
END OF BLOCK   13           CRACK LENGTH =  1.8265E-02
   GROWTH THIS BLOCK =  1.4031E-03     TOTAL GROWTH =  7.8453E-03

END OF SEGMENT   100 OF BLOCK   14      CRACK LENGTH =  1.[illegible]E-02
END OF SEGMENT   200 OF BLOCK   14      CRACK LENGTH =  2.075[illegible]E-02
END OF BLOCK   14           CRACK LENGTH =  2.075[illegible]E-02
   GROWTH THIS BLOCK =  2.486[illegible]E-03     TOTAL GROWTH =  1.[illegible]E-02

END OF SEGMENT   100 OF BLOCK   15      CRACK LENGTH =  2.36[illegible]

[illegible]
[illegible]
```

TABLE 5. CONTINUED

BLOCK IN SPECTRUM	15
SEGMENT NUMBER	122
MISSION NUMBER	5
FLIGHT NUMBER	2922
LAYER IN MISSION	29
ACCUMULATED CYCLES	8.6597E+04
CRACK LENGTH	3.4084E-02
KMAX APPLIED	5.0955E+07
KMAX EFFECTIVE	5.0955E+07
DELTA K	4.2463E+07
DA/DN	3.8954E-05

TABLE 6. INPUT FILE FOR CRACKS IV FOR PROBLEM 2. FOR KEYWORD DEFINITION SEE REFERENCE 3.

```
TITLE
1
SWISS SPECIMEN RUN
EQUATION
R-DA/DN
MATERIAL
ALUMINIUM ALLOY
48.6E6 458.0E6
THRESHOLD
2.1E6 1.0
LIMITS
0.00035590 0.0 0.0 0.95
ANALYSIS
RETARD      1 0 4.20 1 0
BETA        5 0.003 0.0003559 0.0009
BETA        9 0.003 0.0009 0.0021
BETA        1 1.44 0.0021 0.00336
BETA        6 0.003 0.00336
END
LOADS
```

TABLE 6. CONTINUED

```
40 1          SWISS SEQUENCES SPECIMEN (24)
1.0
MAX-MIN
    0.3300000E+08  0.0000000E+00      1
    0.1200000E+09  0.4500000E+08      1
    0.9000000E+08  0.3000000E+08      1
    0.1050000E+09  0.6000000E+08      1
    0.9000000E+08  0.6000000E+08      1
    0.1350000E+09  0.1050000E+09      1
    0.1350000E+09  0.9000000E+08      1
    0.1050000E+09  0.7500000E+08      1
    0.1200000E+09  0.4500000E+08      1
    0.9000000E+08  0.3000000E+08      1
    0.1650000E+09  0.6000000E+08      1
    0.1650000E+09  0.6000000E+08      1
    0.1350000E+09  0.9000000E+08      1
    0.1500000E+09  0.3000000E+08      1
    0.1950000E+09  0.9000000E+08      1
    0.1350000E+09  0.1500000E+08      1
    0.1950000E+09 -0.6000000E+08      1
    0.1500000E+09  0.1500000E+08      1
    0.9000000E+08  0.3000000E+08      1
    0.1800000E+09  0.4500000E+08      1
    0.9000000E+08  0.4500000E+08      1
    0.1350000E+09  0.4500000E+08      1
    0.1350000E+09  0.6000000E+08      1
    0.1800000E+09  0.3000000E+08      1
    0.1050000E+09  0.3000000E+08      1
END
MAX-MIN
    0.3300000E+08  0.0000000E+00      1
    0.1200000E+09  0.4500000E+08      1
    0.9000000E+08  0.3000000E+08      1
    0.1050000E+09  0.6000000E+08      1
    0.9000000E+08  0.6000000E+08      1
    0.1350000E+09  0.1050000E+09      1
    0.1350000E+09  0.9000000E+08      1
    0.1050000E+09  0.7500000E+08      1
    0.1200000E+09  0.4500000E+08      1
    0.9000000E+08  0.3000000E+08      1
    0.1200000E+09  0.6000000E+08      1
    0.1200000E+09  0.6000000E+08      1
    0.1350000E+09  0.9000000E+08      1
    0.1200000E+09  0.3000000E+08      1
    0.1050000E+09  0.3000000E+08      1
    0.1950000E+09  0.9000000E+08      1
    0.1350000E+09 -0.6000000E+08      1
    0.2250000E+09 -0.7500000E+08      1
    0.1500000E+09  0.1500000E+08      1
    0.9000000E+08  0.3000000E+08      1
    0.1200000E+09  0.4500000E+08      1
    0.9000000E+08  0.4500000E+08      1
    0.1350000E+09  0.4500000E+08      1
    0.1350000E+09  0.6000000E+08      1
    0.1200000E+09  0.3000000E+08      1
    0.1050000E+09  0.3000000E+08      1
END
```

TABLE 6. CONTINUED

```
MAX-MIN
     0.3300000E+08  0.0000000E+00        1
     0.1200000E+09  0.4500000E+08        1
     0.9000000E+08  0.3000000E+08        1
     0.1050000E+09  0.6000000E+08        1
     0.9000000E+08  0.6000000E+08        1
     0.1350000E+09  0.1050000E+09        1
     0.1350000E+09  0.9000000E+08        1
     0.1050000E+09  0.7500000E+08        1
     0.1200000E+09  0.4500000E+08        1
     0.9000000E+08  0.3000000E+08        1
     0.1200000E+09  0.6000000E+08        1
     0.1200000E+09  0.6000000E+08        1
     0.1350000E+09  0.9000000E+08        1
     0.1200000E+09  0.3000000E+08        1
     0.1050000E+09  0.3000000E+08        1
     0.1950000E+09  0.9000000E+08        1
     0.1350000E+09  0.1500000E+08        1
     0.1950000E+09 -0.6000000E+08        1
     0.1500000E+09  0.1500000E+08        1
     0.9000000E+08  0.3000000E+08        1
     0.1800000E+09  0.4500000E+08        1
     0.9000000E+08  0.4500000E+08        1
     0.1350000E+09  0.4500000E+08        1
     0.1350000E+09  0.6000000E+08        1
     0.1800000E+09  0.3000000E+08        1
END
MAX-MIN
     0.3300000E+08  0.0000000E+00        1
     0.1200000E+09  0.4500000E+08        1
     0.9000000E+08  0.3000000E+08        1
     0.1050000E+09  0.6000000E+08        1
     0.9000000E+08  0.6000000E+08        1
     0.1350000E+09  0.1050000E+09        1
     0.1350000E+09  0.9000000E+08        1
     0.1050000E+09  0.7500000E+08        1
     0.1200000E+09  0.4500000E+08        1
     0.9000000E+08  0.3000000E+08        1
     0.1200000E+09  0.6000000E+08        1
     0.1200000E+09  0.6000000E+08        1
     0.1350000E+09  0.9000000E+08        1
     0.1200000E+09  0.3000000E+08        1
     0.1050000E+09  0.3000000E+08        1
     0.1800000E+09  0.9000000E+08        1
     0.1350000E+09 -0.3000000E+08        1
     0.2100000E+09 -0.4500000E+08        1
     0.9000000E+08  0.1500000E+08        1
     0.9000000E+08  0.3000000E+08        1
     0.1800000E+09  0.4500000E+08        1
     0.9000000E+08  0.4500000E+08        1
     0.1350000E+09  0.4500000E+08        1
     0.9000000E+08  0.6000000E+08        1
     0.1800000E+09  0.3000000E+08        1
END
```

TABLE 6. CONTINUED

```
MAX-MIN
     0.3300000E+08  0.0000000E+00        1
     0.9000000E+08  0.3000000E+08        1
     0.9000000E+08  0.3000000E+08        1
     0.1200000E+09  0.3000000E+08        1
     0.9000000E+08  0.6000000E+08        1
     0.1350000E+09  0.3000000E+08        1
     0.1050000E+09  0.3000000E+08        1
     0.1200000E+09  0.1500000E+08        1
     0.1350000E+09  0.3000000E+08        1
     0.1200000E+09  0.3000000E+08        1
     0.1350000E+09  0.3000000E+08        1
     0.1350000E+09  0.3000000E+08        1
     0.9000000E+08  0.3000000E+08        1
     0.1500000E+09  0.1500000E+08        1
     0.1200000E+09  0.4500000E+08        1
     0.1050000E+09  0.3000000E+08        1
     0.1200000E+09  0.4500000E+08        1
     0.9000000E+08  0.1500000E+08        1
     0.1200000E+09  0.3000000E+08        1
END
MAX-MIN
     0.3300000E+08  0.0000000E+00        1
     0.9000000E+08  0.3000000E+08        1
     0.9000000E+08  0.3000000E+08        1
     0.1200000E+09  0.3000000E+08        1
     0.9000000E+08  0.6000000E+08        1
     0.1350000E+09  0.3000000E+08        1
     0.1050000E+09  0.3000000E+08        1
     0.1200000E+09  0.1500000E+08        1
     0.1350000E+09  0.3000000E+08        1
     0.1200000E+09  0.3000000E+08        1
     0.1350000E+09  0.3000000E+08        1
     0.1350000E+09  0.3000000E+08        1
     0.9000000E+08  0.3000000E+08        1
     0.1500000E+09  0.1500000E+08        1
     0.1200000E+09  0.4500000E+08        1
     0.1050000E+09  0.3000000E+08        1
     0.1200000E+09  0.4500000E+08        1
     0.9000000E+08  0.1500000E+08        1
     0.1200000E+09  0.3000000E+08        1
END
```

```
MAX-MIN
      0.3300000E+08  0.0000000E+00        1
      0.1200000E+09  0.4500000E+08        1
      0.9000000E+08  0.3000000E+08        1
      0.1050000E+09  0.6000000E+08        1
      0.9000000E+08  0.6000000E+08        1
      0.1350000E+09  0.1050000E+09        1
      0.1350000E+09  0.9000000E+08        1
      0.1050000E+09  0.7500000E+08        1
      0.1200000E+09  0.4500000E+08        1
      0.9000000E+08  0.3000000E+08        1
      0.1200000E+09  0.6000000E+08        1
      0.1200000E+09  0.6000000E+08        1
      0.1350000E+09  0.9000000E+08        1
      0.1200000E+09  0.3000000E+08        1
      0.1050000E+09  0.3000000E+08        1
      0.1800000E+09  0.9000000E+08        1
      0.1350000E+09 -0.3000000E+08        1
      0.1950000E+09 -0.4500000E+08        1
      0.9000000E+08  0.1500000E+08        1
      0.9000000E+08  0.3000000E+08        1
      0.1800000E+09  0.4500000E+08        1
      0.9000000E+08  0.4500000E+08        1
      0.1350000E+09  0.4500000E+08        1
      0.1350000E+09  0.6000000E+08        1
      0.1800000E+09  0.3000000E+08        1
      0.1050000E+09  0.3000000E+08        1
END
MAX-MIN
      0.3300000E+08  0.0000000E+00        1
      0.9000000E+08  0.3000000E+08        1
      0.9000000E+08  0.3000000E+08        1
      0.1200000E+09  0.3000000E+08        1
      0.9000000E+08  0.6000000E+08        1
      0.1350000E+09  0.3000000E+08        1
      0.1050000E+09  0.3000000E+08        1
      0.1200000E+09  0.1500000E+08        1
      0.1350000E+09  0.3000000E+08        1
      0.1200000E+09  0.3000000E+08        1
      0.1350000E+09  0.3000000E+08        1
      0.1350000E+09  0.3000000E+08        1
      0.9000000E+08  0.3000000E+08        1
      0.1500000E+09  0.1500000E+08        1
      0.1200000E+09  0.4500000E+08        1
      0.1050000E+09  0.3000000E+08        1
      0.1200000E+09  0.4500000E+08        1
      0.9000000E+08  0.1500000E+08        1
      0.1200000E+09  0.3000000E+08        1
END
```

TABLE 6. CONTINUED

MAX-MIN

0.3300000E+08	0.0000000E+00	1
0.1200000E+09	0.1500000E+08	1
0.1050000E+09	0.7500000E+08	1
0.1200000E+09	0.4500000E+08	1
0.1200000E+09	0.3000000E+08	1
0.1050000E+09	0.3000000E+08	1
0.1500000E+09	0.1500000E+08	1
0.1050000E+09	0.3000000E+08	1
0.9000000E+08	0.6000000E+08	1
0.1050000E+09	0.3000000E+08	1
0.1050000E+09	0.4500000E+08	1
0.9000000E+08	0.3000000E+08	1
0.1200000E+09	0.4500000E+08	1
0.1050000E+09	0.3000000E+08	1
0.1500000E+09	0.3000000E+08	1
0.1050000E+09	0.3000000E+08	1
0.9000000E+08	0.3000000E+08	1
0.9000000E+08	0.3000000E+08	1
0.1050000E+09	0.3000000E+08	1
0.1650000E+09	0.7500000E+08	1
0.9000000E+08	0.3000000E+08	1
0.1650000E+09	0.6000000E+08	1
0.1050000E+09	0.7500000E+08	1
0.1650000E+09	0.1500000E+08	1
0.1650000E+09	0.6000000E+08	1
0.1200000E+09	0.6000000E+08	1
0.1350000E+09	0.7500000E+08	1
0.1200000E+09	0.3000000E+08	1
0.9000000E+08	0.3000000E+08	1

END

TABLE 6. CONTINUED

MAX-HT

0.3300000E+08	-0.1500000E+08	1
0.1200000E+09	0.3000000E+08	1
0.1500000E+09	0.6000000E+08	1
0.1050000E+09	0.3000000E+08	1
0.1500000E+09	0.3000000E+08	1
0.1200000E+09	0.4500000E+08	1
0.1050000E+09	0.3000000E+08	1
0.1200000E+09	0.6000000E+08	1
0.1050000E+09	0.4500000E+08	1
0.9000000E+08	-0.1500000E+08	1
0.1050000E+09	0.3000000E+08	1
0.1650000E+09	0.4500000E+08	1
0.1050000E+09	0.0000000E+00	1
0.1050000E+09	0.3000000E+08	1
0.1200000E+09	0.4500000E+08	1
0.9000000E+08	0.1500000E+08	1
0.1050000E+09	0.6000000E+08	1
0.1200000E+09	0.3000000E+08	1
0.1200000E+09	0.0000000E+00	1
0.1650000E+09	0.1500000E+08	1
0.1050000E+09	0.0000000E+00	1
0.1350000E+09	0.7500000E+08	1
0.1350000E+09	0.3000000E+08	1
0.1350000E+09	0.0000000E+00	1
0.1500000E+09	0.6000000E+08	1
0.1350000E+09	0.6000000E+08	1
0.1050000E+09	0.1500000E+08	1
0.1500000E+09	0.3000000E+08	1
0.1200000E+09	0.3000000E+08	1
0.1050000E+09	0.0000000E+00	1
0.9000000E+08	0.3000000E+08	1
0.9000000E+08	0.3000000E+08	1

END

TABLE 6. CONTINUED

MAX-MIN

0.3300000E+08	-0.1500000E+08	1
0.1200000E+09	0.3000000E+08	1
0.1500000E+09	0.6000000E+08	1
0.1050000E+09	0.3000000E+08	1
0.1500000E+09	0.3000000E+08	1
0.1200000E+09	0.4500000E+08	1
0.1050000E+09	0.3000000E+08	1
0.1200000E+09	0.6000000E+08	1
0.1050000E+09	0.4500000E+08	1
0.9000000E+08	-0.1500000E+08	1
0.1050000E+09	0.3000000E+08	1
0.1650000E+09	0.4500000E+08	1
0.1050000E+09	0.0000000E+00	1
0.1050000E+09	0.3000000E+08	1
0.1200000E+09	0.4500000E+08	1
0.9000000E+08	0.1500000E+08	1
0.1050000E+09	0.6000000E+08	1
0.1200000E+09	0.3000000E+08	1
0.1200000E+09	0.0000000E+00	1
0.1650000E+09	0.1500000E+08	1
0.1050000E+09	0.0000000E+00	1
0.1350000E+09	0.7500000E+08	1
0.1350000E+09	0.3000000E+08	1
0.1350000E+09	0.0000000E+00	1
0.1500000E+09	0.6000000E+08	1
0.1350000E+09	0.6000000E+08	1
0.1050000E+09	0.1500000E+08	1
0.1500000E+09	0.3000000E+08	1
0.1200000E+09	0.3000000E+08	1
0.1050000E+09	0.0000000E+00	1
0.9000000E+08	0.3000000E+08	1
0.9000000E+08	0.3000000E+08	1

END

TABLE 6. CONTINUED

```
MAX-MIN
     0.3300000E+08 -0.1500000E+08          1
     0.1200000E+09  0.3000000E+08          1
     0.1500000E+09  0.6000000E+08          1
     0.1050000E+09  0.3000000E+08          1
     0.1500000E+09  0.3000000E+08          1
     0.1200000E+09  0.4500000E+08          1
     0.1050000E+09  0.3000000E+08          1
     0.1200000E+09  0.6000000E+08          1
     0.1050000E+09  0.4500000E+08          1
     0.9000000E+08 -0.1500000E+08          1
     0.1050000E+09  0.3000000E+08          1
     0.1650000E+09  0.4500000E+08          1
     0.1050000E+09  0.0000000E+00          1
     0.1050000E+09  0.3000000E+08          1
     0.1200000E+09  0.4500000E+08          1
     0.9000000E+08  0.1500000E+08          1
     0.1050000E+09  0.6000000E+08          1
     0.1200000E+09  0.3000000E+08          1
     0.1200000E+09  0.0000000E+00          1
     0.1650000E+09  0.1500000E+08          1
     0.1050000E+09  0.0000000E+00          1
     0.1350000E+09  0.7500000E+08          1
     0.1350000E+09  0.3000000E+08          1
     0.1350000E+09  0.0000000E+00          1
     0.1500000E+09  0.6000000E+08          1
     0.1350000E+09  0.6000000E+08          1
     0.1050000E+09  0.1500000E+08          1
     0.1500000E+09  0.3000000E+08          1
     0.1200000E+09  0.3000000E+08          1
     0.1050000E+09  0.0000000E+00          1
     0.9000000E+08  0.3000000E+08          1
     0.9000000E+08  0.3000000E+08          1
END
```

TABLE 6. CONTINUED

```
MAX-MIN
     0.3300000E+08 -0.1500000E+08        1
     0.1200000E+09  0.3000000E+08        1
     0.1500000E+09  0.6000000E+08        1
     0.1050000E+09  0.3000000E+08        1
     0.1500000E+09  0.3000000E+08        1
     0.1200000E+09  0.4500000E+08        1
     0.1050000E+09  0.3000000E+08        1
     0.1200000E+09  0.6000000E+08        1
     0.1050000E+09  0.4500000E+08        1
     0.9000000E+08 -0.1500000E+08        1
     0.1050000E+09  0.3000000E+08        1
     0.1650000E+09  0.4500000E+08        1
     0.1050000E+09  0.0000000E+00        1
     0.1050000E+09  0.3000000E+08        1
     0.1200000E+09  0.4500000E+08        1
     0.9000000E+08  0.1500000E+08        1
     0.1050000E+09  0.6000000E+08        1
     0.1200000E+09  0.3000000E+08        1
     0.1200000E+09  0.0000000E+00        1
     0.1650000E+09  0.1500000E+08        1
     0.1050000E+09  0.0000000E+00        1
     0.1350000E+09  0.7500000E+08        1
     0.1350000E+09  0.3000000E+08        1
     0.1350000E+09  0.0000000E+00        1
     0.1500000E+09  0.6000000E+08        1
     0.1350000E+09  0.6000000E+08        1
     0.1050000E+09  0.1500000E+08        1
     0.1500000E+09  0.3000000E+08        1
     0.1200000E+09  0.3000000E+08        1
     0.1050000E+09  0.0000000E+00        1
     0.9000000E+08  0.3000000E+08        1
     0.9000000E+08  0.3000000E+08        1
END
```

TABLE 6. CONTINUED

```
MAX-MIN
     0.3300000E+08   0.0000000E+00        1
     0.9000000E+08   0.1500000E+08        1
END
MAX-MIN
     0.3300000E+08   0.0000000E+00        1
     0.9000000E+08   0.1500000E+08        1
END
MAX-MIN
     0.3300000E+08   0.0000000E+00        1
     0.9000000E+08   0.1500000E+08        1
END
MAX-MIN
     0.3300000E+08   0.0000000E+00        1
     0.9000000E+08   0.1500000E+08        1
END
MAX-MIN
     0.3300000E+08   0.0000000E+00        1
     0.9000000E+08   0.0000000E+00        1
END
MAX-MIN
     0.3300000E+08   0.0000000E+00        1
     0.9000000E+08   0.0000000E+00        1
END
MAX-MIN
     0.3300000E+08   0.0000000E+00        1
     0.9000000E+08   0.0000000E+00        1
END
```

TABLE 6. CONTINUED

```
MAX-MIN
      0.3300000E+08   0.0000000E+00          1
      0.9000000E+08   0.3000000E+08          1
      0.9000000E+08   0.1500000E+08          1
      0.9000000E+08   0.6000000E+08          1
      0.9000000E+08   0.3000000E+08          1
      0.1050000E+09   0.1500000E+08          1
      0.1050000E+09   0.3000000E+08          1
      0.9000000E+08   0.3000000E+08          1
      0.9000000E+08   0.3000000E+08          1
      0.1050000E+09   0.6000000E+08          1
END
MAX-MIN
      0.3300000E+08   0.0000000E+00          1
      0.9000000E+08   0.3000000E+08          1
      0.9000000E+08   0.1500000E+08          1
      0.9000000E+08   0.6000000E+08          1
      0.9000000E+08   0.3000000E+08          1
      0.1050000E+09   0.1500000E+08          1
      0.1050000E+09   0.3000000E+08          1
      0.9000000E+08   0.3000000E+08          1
      0.9000000E+08   0.3000000E+08          1
      0.1050000E+09   0.6000000E+08          1
END
MAX-MIN
      0.3300000E+08   0.0000000E+00          1
      0.9000000E+08   0.3000000E+08          1
      0.9000000E+08   0.1500000E+08          1
      0.9000000E+08   0.6000000E+08          1
      0.9000000E+08   0.3000000E+08          1
      0.1050000E+09   0.1500000E+08          1
      0.1050000E+09   0.3000000E+08          1
      0.9000000E+08   0.3000000E+08          1
      0.9000000E+08   0.3000000E+08          1
      0.1050000E+09   0.6000000E+08          1
END
MAX-MIN
      0.3300000E+08   0.0000000E+00          1
      0.9000000E+08   0.3000000E+08          1
      0.9000000E+08   0.1500000E+08          1
      0.9000000E+08   0.6000000E+08          1
      0.9000000E+08   0.3000000E+08          1
      0.1050000E+09   0.1500000E+08          1
      0.1050000E+09   0.3000000E+08          1
      0.9000000E+08   0.3000000E+08          1
      0.9000000E+08   0.3000000E+08          1
      0.1050000E+09   0.6000000E+08          1
END
```

TABLE 6. CONTINUED

```
END LOADS
SPECTRUM
200 1
1 14
1 10
1 6
1 11
1 15
1 16
1 17
1 21
1 23
1 13
1 11
1 22
1 24
1 5
1 12
1 18
1 14
1 5
1 23
1 13
1 3
1 8
1 21
1 17
1 11
1 13
1 15
1 24
1 21
1 11
1 23
1 22
1 7
1 11
1 22
1 6
1 10
1 14
1 16
1 8
1 14
1 12
1 21
1 6
```

TABLE 6. CONTINUED

1	17
1	13
1	10
1	2
1	11
1	21
1	23
1	13
1	23
1	15
1	3
1	19
1	14
1	7
1	15
1	12
1	24
1	23
1	16
1	21
1	22
1	19
1	13
1	22
1	21
1	8
1	24
1	17
1	10
1	9
1	15
1	13
1	16
1	12
1	14
1	21
1	14
1	10
1	15
1	23
1	24
1	21
1	12
1	17
1	19
1	16
1	6
1	11
1	13
1	11
1	20
1	15

TABLE 6. CONTINUED

1	7
1	23
1	4
1	7
1	5
1	20
1	11
1	17
1	18
1	5
1	10
1	13
1	4
1	12
1	22
1	13
1	23
1	11
1	19
1	10
1	15
1	18
1	9
1	11
1	9
1	5
1	5
1	16
1	13
1	17
1	21
1	22
1	15
1	17
1	21
1	12
1	24
1	14
1	13
1	24
1	7
1	23
1	16
1	22
1	14
1	10
1	21
1	4
1	15
1	5
1	15
1	24
1	12
1	2
1	11
1	23
1	8
1	11
1	23
1	13

TABLE 6. CONTINUED

```
1 9
1 22
1 17
1 8
1 22
1 4
1 12
1 11
1 3
1 14
1 11
1 9
1 11
1 1
1 14
1 4
1 21
1 10
1 13
1 15
1 21
1 17
1 23
1 15
1 6
1 24
1 11
1 17
1 24
1 4
1 21
1 12
1 20
1 10
1 16
1 5
1 14
1 23
1 13
1 23
1 17
1 15
1 14
1 16
PRINT
1 100 0 0 0 1000
END DATA
```

TABLE 7. OUTPUT FROM CRACKS IV FOR PROBLEM 2.

CRACKS-IV VERSION 5, 04/26/79 R.M. ENGLE JR.
ARL ADAPTATION - JANUARY 1980

CASE 1 RUN 1
SWISS SPECIMEN RUN
DIRECT INPUT OF DA/DN VS DELTAK FOR SEVERAL VALUES OF STRESS RATIO R.
ALUMINIUM ALLOY

KSUBO = 4.8600E+07 YIELD STRESS = 4.5800E+08

THRESHOLD DELTA K = 2.1000E+06*(1.0- 1.000*R)

INITIAL HALF CRACK LENGTH = 3.5590E-04
INITIAL CYCLE NUMBER = 0.00
R CUTOFF = 0.950
AUTOMATIC UNRETARDED SOLUTION SUPPRESSED
WHEELER'S RETARDATION MODEL WITH SMALLM = 4.200
PLANE STRESS YIELD ZONE CONDITION ASSUMED
CORRECTION FACTOR BETA(5) IS UNIAXIAL BOWIE SOLUTION FOR A SINGLE CRACK
FROM A CIRCULAR HOLE OF RADIUS R = 3.0000E-03
APPLIED FROM A = 3.5590E-04 TO A = 9.0000E-04
CORRECTION FACTOR BETA(9) IS UNIAXIAL LIU SOLUTION FOR A QUARTER CRACK
FROM A DOUBLE HOLE OF RADIUS R = 3.0000E-03
APPLIED FROM A = 9.0000E-04 TO A = 2.1000E-03
CORRECTION FACTOR BETA(1) IS A CONSTANT
BETA(1) = 1.440
APPLIED FROM A= 2.1000E-03 TO A = 3.3600E-03
CORRECTION FACTOR BETA(6) IS UNIAXIAL BOWIE SOLUTION FOR TWO CRACKS
FROM A CIRCULAR HOLE OF RADIUS R = 3.0000E-03
APPLIED FROM A = 3.3600E-03 TO A = 1.0000E+39
MULTIPLICATION FACTOR = 1.000000
SWISS SEQUENCES SPECIMEN (24)

40 BLOCKS IN SPECTRUM

END OF INPUT
**********CRACKS IV ANALYSIS**********

SWISS SEQUENCES SPECIMEN (24)

FLT	MSN	LYR	CYCLES	A	DELTA K	K MAX	DADN	RETARD
1	14	1	1.0	0.0004	.339E+07	.339E+07	2.504E-09	1.000
1	14	2	2.0	0.0004	.462E+07	.770E+07	8.211E-09	1.000
1	14	3	3.0	0.0004	.462E+07	.616E+07	9.332E-10	0.153
1	14	4	4.0	0.0004	.462E+07	.616E+07	9.333E-10	0.153
1	14	5	5.0	0.0004	.462E+07	.616E+07	9.334E-10	0.153
1	14	6	6.0	0.0004	.308E+07	.616E+07	4.640E-10	0.153
1	14	7	7.0	0.0004	.616E+07	.925E+07	1.965E-08	1.000
1	14	8	8.0	0.0004	.308E+07	.616E+07	1.003E-10	0.033
1	14	9	9.0	0.0004	.462E+07	.771E+07	1.776E-09	0.216

END OF SEGMENT 100 OF BLOCK 1 CRACK LENGTH = 3.7901E-04
END OF SEGMENT 200 OF BLOCK 1 CRACK LENGTH = 3.9381E-04
END OF BLOCK 1 CRACK LENGTH = 3.9381E-04
GROWTH THIS BLOCK = 3.7915E-05 TOTAL GROWTH = 3.7915E-05

END OF SEGMENT 100 OF BLOCK 2 CRACK LENGTH = 4.0363E-04
END OF SEGMENT 200 OF BLOCK 2 CRACK LENGTH = 4.2095E-04
END OF BLOCK 2 CRACK LENGTH = 4.2095E-04
GROWTH THIS BLOCK = 2.7125E-05 TOTAL GROWTH = [illegible]

TABLE 7. CONTINUED

```
CRACKS-IV    VERSION 5, 04/26/79    R.M. ENGLE JR.
ARL ADAPTATION - JANUARY 1980

CASE  1     RUN  1
SWISS SPECIMEN RUN
DIRECT INPUT OF DA/DN VS DELTAK FOR SEVERAL VALUES OF STRESS RATIO R.
ALUMINIUM ALLOY

KSUBQ = 4.8600E+07      YIELD STRESS = 4.5800E+08

THRESHOLD DELTA K = 2.1000E+06*(1.0- 1.000*R)

INITIAL HALF CRACK LENGTH =  3.5590E-04
INITIAL CYCLE NUMBER =       0.00
R CUTOFF = 0.950
AUTOMATIC UNRETARDED SOLUTION SUPPRESSED
WHEELER'S RETARDATION MODEL WITH SMALLM = 4.200
PLANE STRESS YIELD ZONE CONDITION ASSUMED
CORRECTION FACTOR BETA(5) IS EMBEDDED CRACK FROM  A HOLE
    (A/D < 0.15) SYMMETRIC.  RADIUS OF HOLE = 3.0000E-03
    APPLIED FROM A =  3.5590E-04 TO A =   9.0000E-04
CORRECTION FACTOR BETA(9) IS UNIAXIAL EMBEDDED CRACK  FROM A HOLE.
    (A/D > 0.15) SYMMETRIC.  RADIUS OF HOLE  RADIUS R = 3.0000E-03
    APPLIED FROM A =   9.0000E-04 TO A =   2.1000E-03
CORRECTION FACTOR BETA(1) IS A CONSTANT
    BETA(1) =  1.440
    APPLIED FROM A= 2.1000E-03 TO A = 3.3600E-03
CORRECTION FACTOR BETA(6) IS UNIAXIAL BOWIE SOLUTION FOR TWO CRACKS
    FROM A CIRCULAR HOLE OF RADIUS R =  3.0000E-03
    APPLIED FROM A =  3.3600E-03 TO A =  1.0000E+38
MULTIPLICATION FACTOR =     1.000000
          SWISS SEQUENCES SPECIMEN (24)

    40 BLOCKS IN SPECTRUM


END OF INPUT
**********CRACKS IV ANALYSIS**********

          SWISS SEQUENCES SPECIMEN (24)
```

FLT	MSN	LYR	CYCLES	A	DELTA K	K MAX	DADN	RETARD
1	14	1	1.0	0.0004	.232E+07	.232E+07	1.495E-09	1.000
1	14	2	2.0	0.0004	.527E+07	.632E+07	7.361E-09	1.000

TABLE 7. CONTINUED

```
END OF SEGMENT   100 OF BLOCK    3      CRACK LENGTH =  4.3174E-04
END OF SEGMENT   200 OF BLOCK    3      CRACK LENGTH =  4.5069E-04
END OF BLOCK     3         CRACK LENGTH =  4.5069E-04
   GROWTH THIS BLOCK =  2.9743E-05      TOTAL GROWTH =  9.4793E-05

END OF SEGMENT   100 OF BLOCK    4      CRACK LENGTH =  4.6256E-04
END OF SEGMENT   200 OF BLOCK    4      CRACK LENGTH =  4.8357E-04
END OF BLOCK     4         CRACK LENGTH =  4.8357E-04
   GROWTH THIS BLOCK =  3.2881E-05      TOTAL GROWTH =  1.2767E-04

END OF SEGMENT   100 OF BLOCK    5      CRACK LENGTH =  4.9676E-04
END OF SEGMENT   200 OF BLOCK    5      CRACK LENGTH =  5.2031E-04
END OF BLOCK     5         CRACK LENGTH =  5.2031E-04
   GROWTH THIS BLOCK =  3.6732E-05      TOTAL GROWTH =  1.6441E-04

END OF SEGMENT   100 OF BLOCK    6      CRACK LENGTH =  5.3501E-04
END OF SEGMENT   200 OF BLOCK    6      CRACK LENGTH =  5.6152E-04
END OF BLOCK     6         CRACK LENGTH =  5.6152E-04
   GROWTH THIS BLOCK =  4.1218E-05      TOTAL GROWTH =  2.0562E-04

END OF SEGMENT   100 OF BLOCK    7      CRACK LENGTH =  5.7804E-04
END OF SEGMENT   200 OF BLOCK    7      CRACK LENGTH =  6.0809E-04
END OF BLOCK     7         CRACK LENGTH =  6.0809E-04
   GROWTH THIS BLOCK =  4.6567E-05      TOTAL GROWTH =  2.5219E-04

END OF SEGMENT   100 OF BLOCK    8      CRACK LENGTH =  6.2688E-04
END OF SEGMENT   200 OF BLOCK    8      CRACK LENGTH =  6.6181E-04
END OF BLOCK     8         CRACK LENGTH =  6.6181E-04
   GROWTH THIS BLOCK =  5.3723E-05      TOTAL GROWTH =  3.0591E-04

END OF SEGMENT   100 OF BLOCK    9      CRACK LENGTH =  6.8406E-04
END OF SEGMENT   200 OF BLOCK    9      CRACK LENGTH =  7.2572E-04
END OF BLOCK     9         CRACK LENGTH =  7.2572E-04
   GROWTH THIS BLOCK =  6.3903E-05      TOTAL GROWTH =  3.6982E-04

END OF SEGMENT   100 OF BLOCK   10      CRACK LENGTH =  7.5264E-04
END OF SEGMENT   200 OF BLOCK   10      CRACK LENGTH =  8.0333E-04
END OF BLOCK    10         CRACK LENGTH =  8.0333E-04
   GROWTH THIS BLOCK =  7.7609E-05      TOTAL GROWTH =  4.4743E-04

END OF SEGMENT   100 OF BLOCK   11      CRACK LENGTH =  8.3692E-04
END OF SEGMENT   200 OF BLOCK   11      CRACK LENGTH =  9.0267E-04
END OF BLOCK    11         CRACK LENGTH =  9.0267E-04
   GROWTH THIS BLOCK =  9.9344E-05      TOTAL GROWTH =  5.4677E-04

END OF SEGMENT   100 OF BLOCK   12      CRACK LENGTH =  9.4464E-04
END OF SEGMENT   200 OF BLOCK   12      CRACK LENGTH =  1.0232E-03
END OF BLOCK    12         CRACK LENGTH =  1.0252E-03
   GROWTH THIS BLOCK =  1.2252E-04      TOTAL GROWTH =  6.6929E-04

END OF SEGMENT   100 OF BLOCK   13      CRACK LENGTH =  1.0752E-03
END OF SEGMENT   200 OF BLOCK   13      CRACK LENGTH =  1.1922E-03
END OF BLOCK    13         CRACK LENGTH =  1.1[illegible]E-03
   GROWTH THIS BLOCK =  1.5697E-04      TOTAL GROWTH =  8.2626E-04
```

TABLE 7. CONTINUED

```
END OF SEGMENT   100 OF BLOCK   14     CRACK LENGTH =  1.2523E-03
END OF SEGMENT   200 OF BLOCK   14     CRACK LENGTH =  1.3964E-03
END OF BLOCK   14          CRACK LENGTH =  1.3964E-03
   GROWTH THIS BLOCK =  2.1423E-04     TOTAL GROWTH =  1.0405E-03

END OF SEGMENT   100 OF BLOCK   15     CRACK LENGTH =  1.4986E-03
END OF SEGMENT   200 OF BLOCK   15     CRACK LENGTH =  1.7224E-03
END OF BLOCK   15          CRACK LENGTH =  1.7224E-03
   GROWTH THIS BLOCK =  3.2601E-04     TOTAL GROWTH =  1.3665E-03

END OF SEGMENT   100 OF BLOCK   16     CRACK LENGTH =  1.8997E-03

KMAX APPLIED EXCEEDS KSUBO.  PROBLEM TERMINATED.
LAST CALCULATED VALUES ARE:

    BLOCK IN SPECTRUM        16
    SEGMENT NUMBER          192
    MISSION NUMBER            5
    FLIGHT NUMBER          3192
    LAYER IN MISSION         29
    ACCUMULATED CYCLES 9.4619E+04
    CRACK LENGTH       8.7498E-03
    KMAX APPLIED       5.0524E+07
    KMAX EFFECTIVE     5.0524E+07
    DELTA K            4.2103E+07
    DA/DN              4.4283E-06
```

TABLE 7. CONTINUED

THIS FILE IS AN OUTPUT FILE FROM CRAX4.
IT INDICATES THE AMOUNT OF EXTRAPOLATION WHICH OCCURS
IN A PARTICULAR RUN OF CRAXS.

CRACK LENGTH	CYCLE	DELTA CRACK	DELTA CYCLE	TOT. DELTA CRACK	TOT. DELTA CYCLE	EXTRA. NO.
.523E-03	.302E+05	.152E-13	.100E+01	.108E-07	1001	1
.815E-03	.606E+05	.252E-13	.100E+01	.108E-07	2001	1

TABLE 8. NON-DIMENSIONAL STRESS INTENSITY AS A FUNCTION OF θ FOR VARIOUS VALUES OF c/a.

c/a	θ Degrees	Q	$K_{Ie} \times M_{2h}/\sigma\sqrt{\pi a}$ $\frac{a}{d} = 0.5$, c = 0.6mm	0.125, 1.50mm	0.25, 3.0mm
0.5	0	2.30	1.85	1.69	1.55
	45		1.44	1.18	0.76
	90		1.10	0.87	0.55
0.75	0	2.30	1.85	1.69	1.55
	45		1.52	1.24	0.80
	90		1.34	1.05	0.66
1.00	0	2.30	1.85	1.69	1.55
	45		1.61	1.31	0.87
	90		1.55	1.22	0.77
1.25	0	1.90	1.82	1.66	1.53
	45		1.76	1.44	0.93
	90		1.71	1.35	0.85
1.50	0	1.60	1.81	1.65	1.52
	45		1.79	1.46	0.94
	90		1.86	1.46	0.92
1.75	0	1.40	1.79	1.63	1.37
	45		1.87	1.53	0.99
	90		1.99	1.56	0.98
2.00	0	1.35	1.70	1.55	1.30
	45		1.87	1.52	0.98
	90		2.02	1.59	1.00
3.00	0	1.10	1.54	1.40	1.17
	45		2.02	1.65	1.06
	90		2.24	1.76	1.11

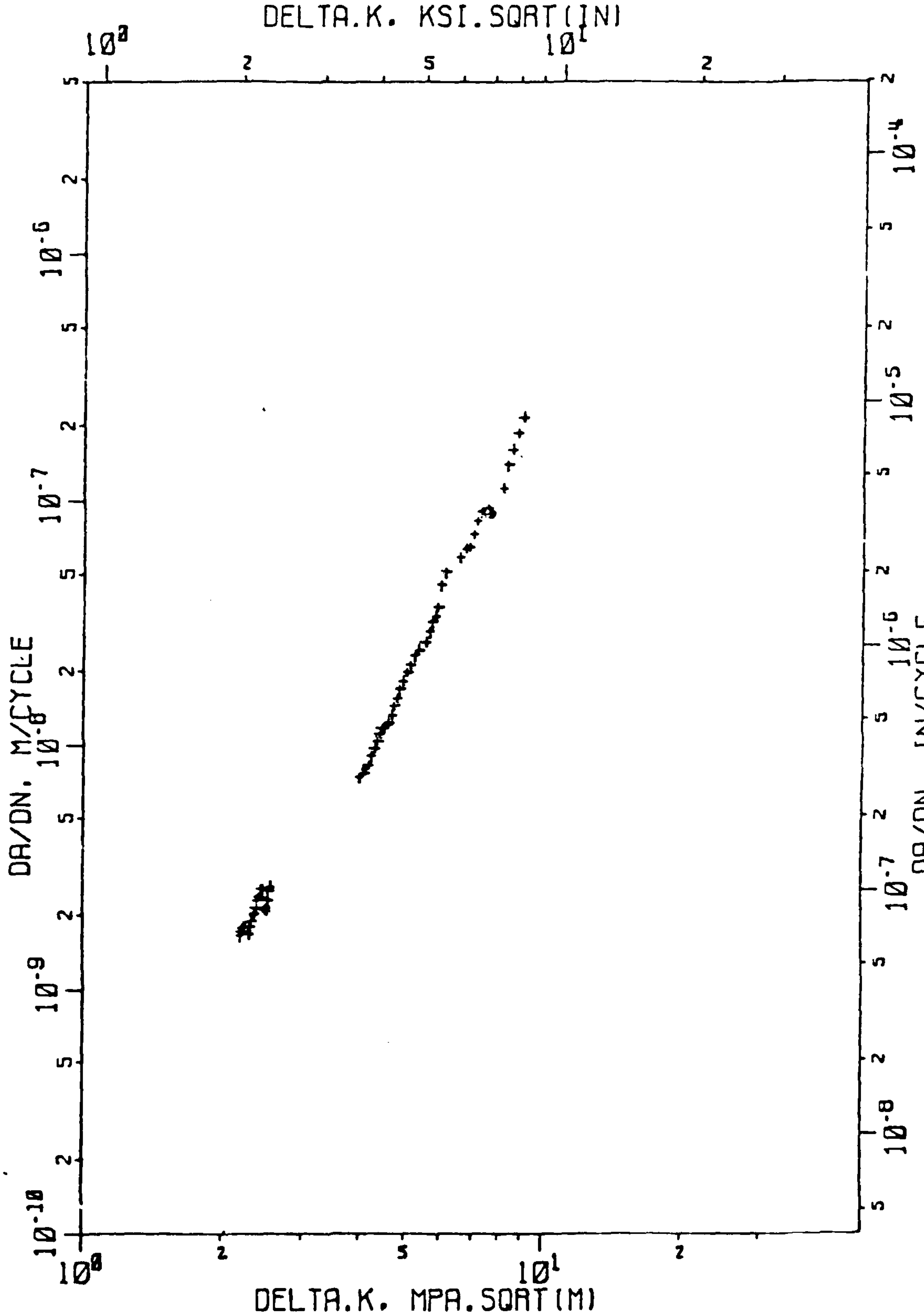


FIG. 1 DA/DN vs DELTA K DATA FOR 5mm THICK CCT SPECIMEN [R = + 0.7]

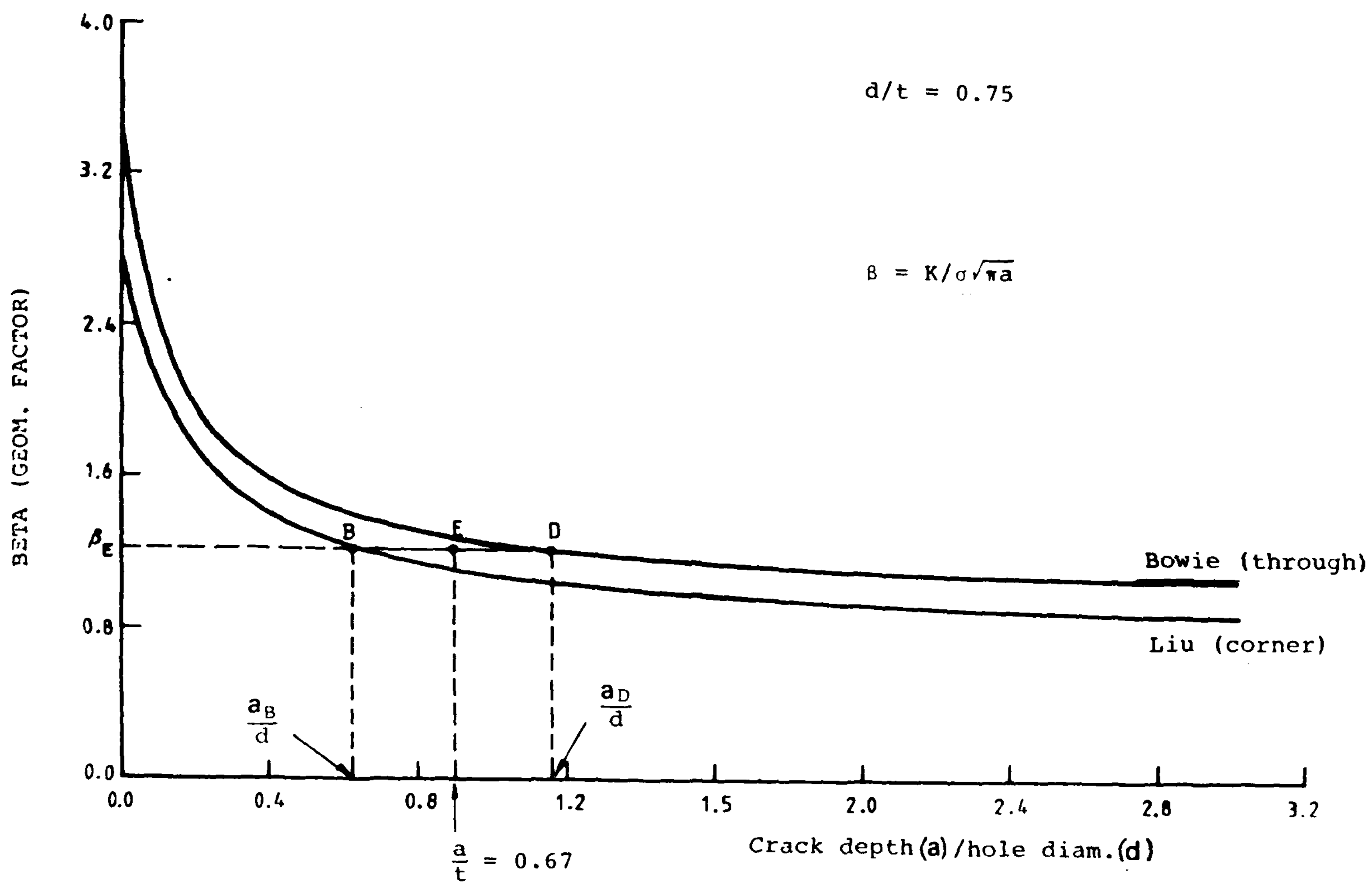


FIG. 2 CRACK GEOMETRY FACTOR 'BETA' vs CRACK DEPTH (FOR SYMMETRIC CRACKS EMANATING FROM HOLES)

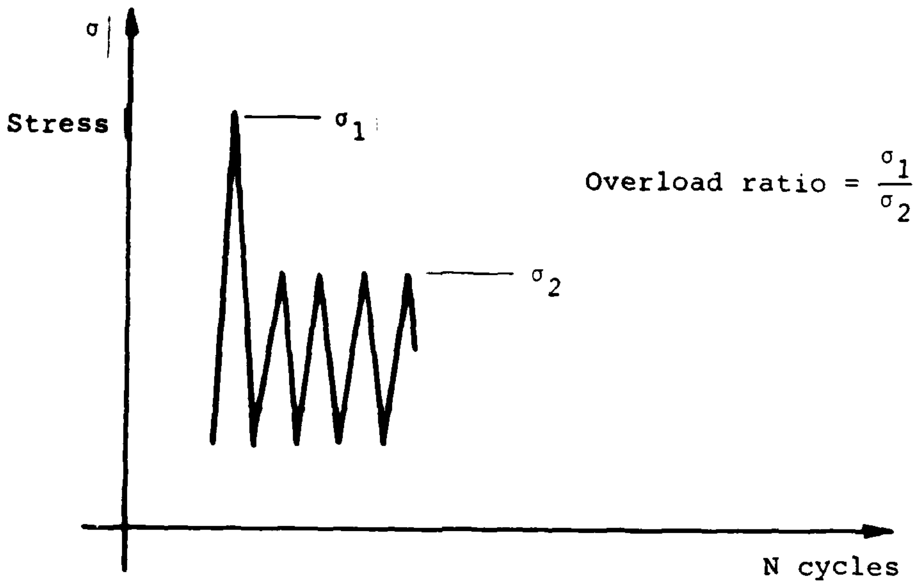


FIG. 3 STRESS vs CYCLES INDICATING THE OVERLOAD RATIO

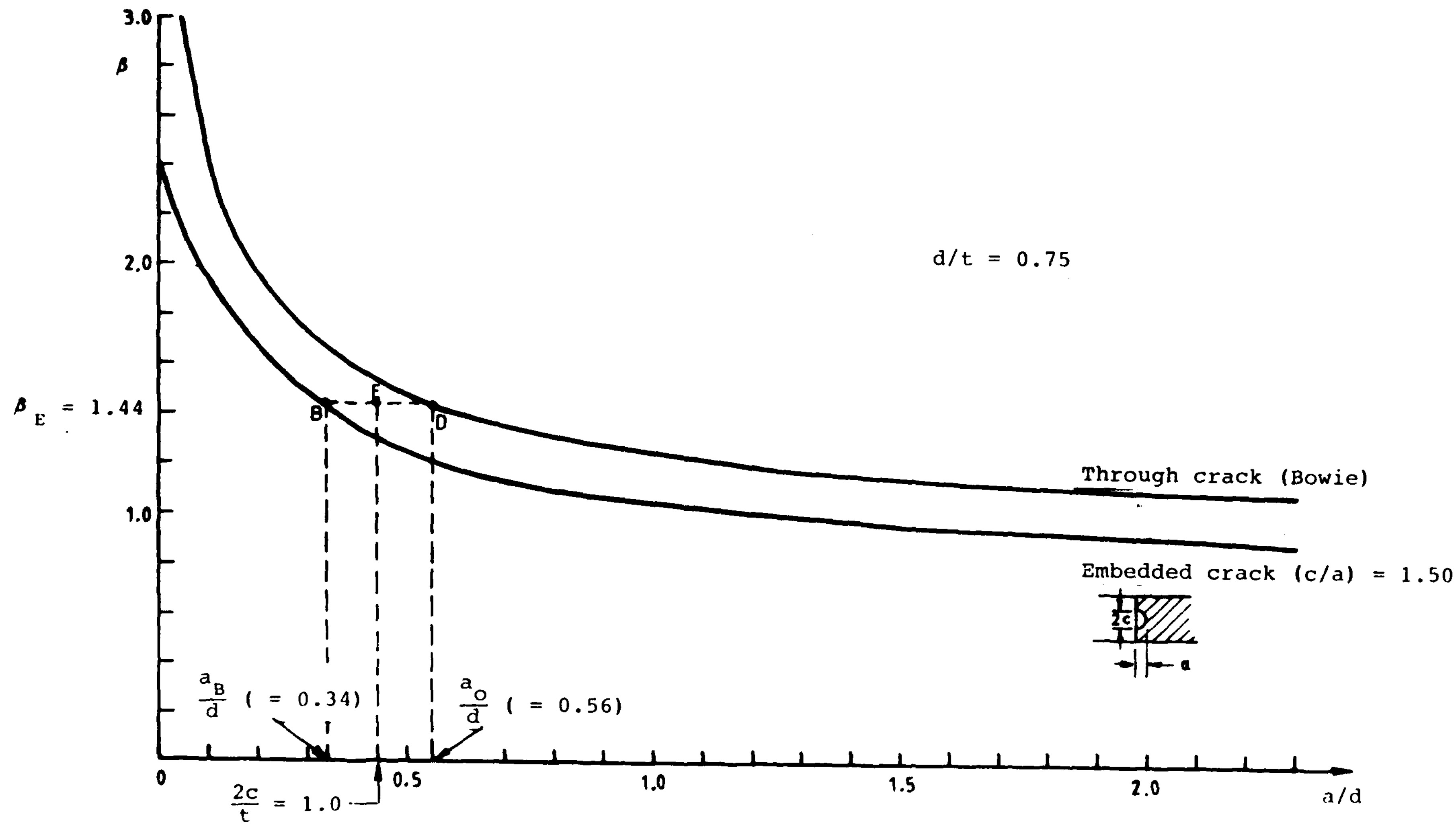


FIG. 4 VARIATION OF CRACK GEOMETRY FACTOR β AS A FUNCTION OF THE RATIO CRACK DEPTH (a) TO HOLE DIAMETER (d). (EMBEDDED CRACK AND THROUGH CRACK).

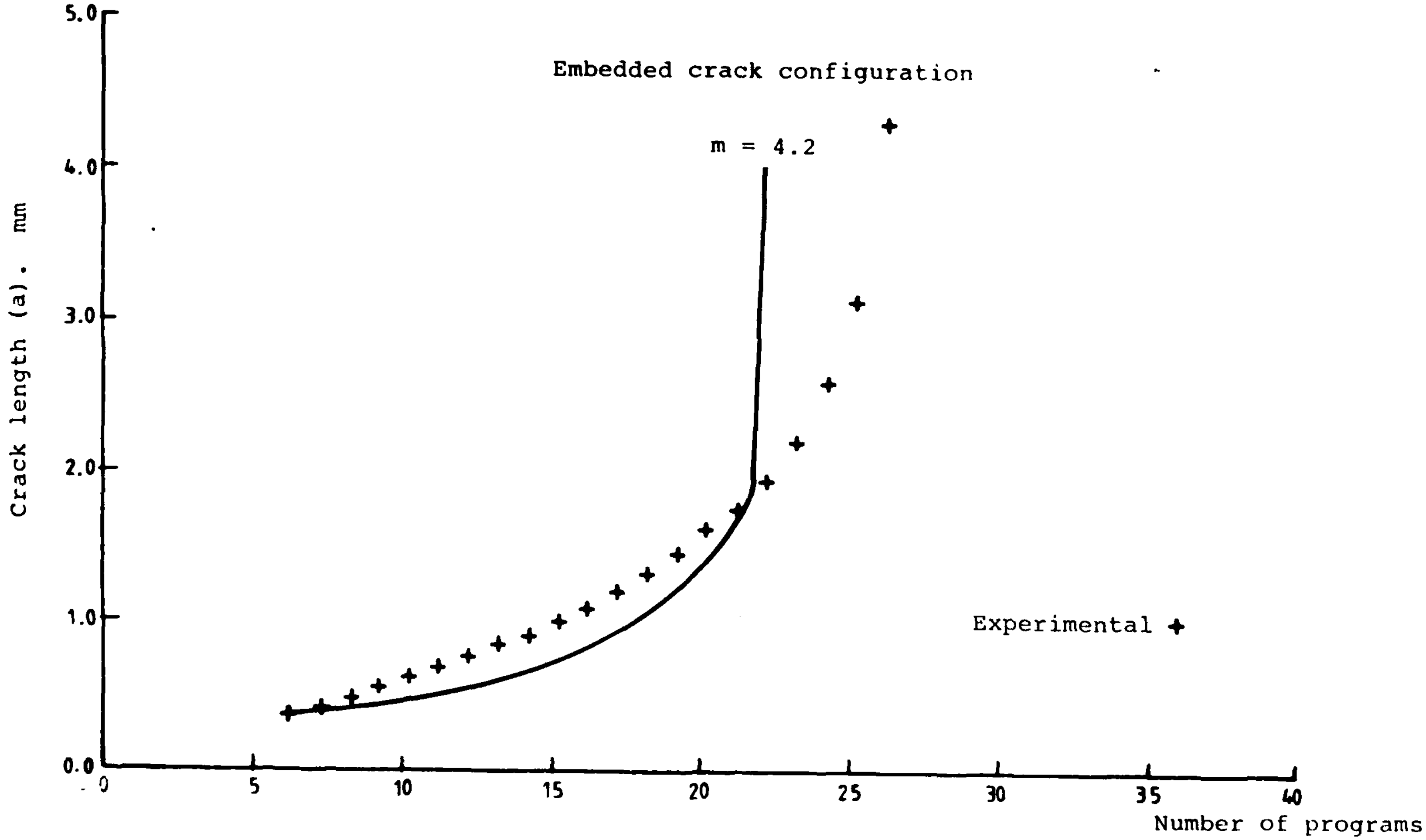


FIG. 5 CRACK GROWTH PREDICTION, USING WHEELER RETARDATION, FOR THE FRAME-BOTTOM SIMULATION SPECIMEN TESTED UNDER THE F+W SEQUENCE (43•80 MPa/g).

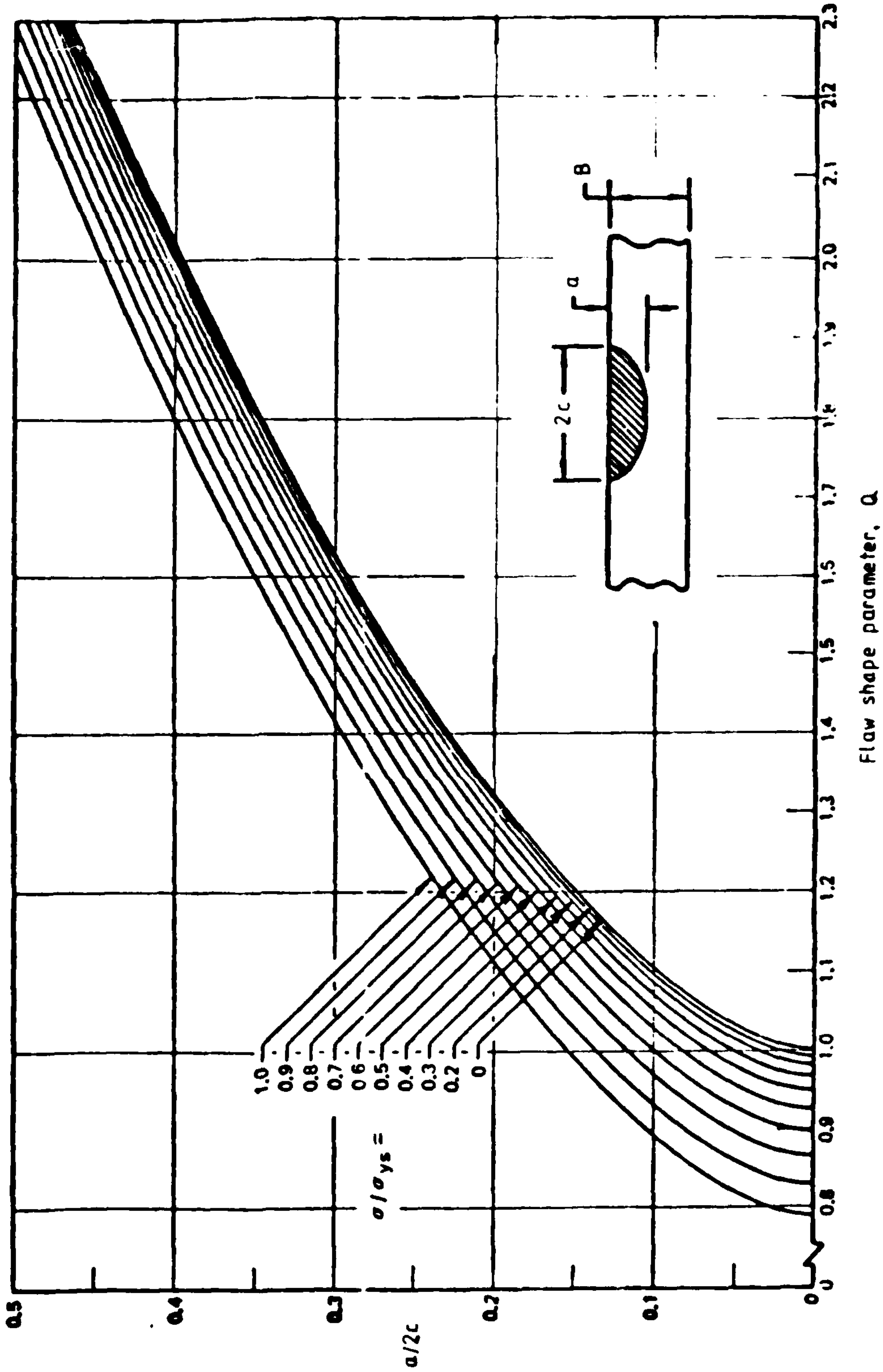


FIG. 6 SHAPE PARAMETER CURVES FOR SURFACE
AND INTERNAL FLAWS

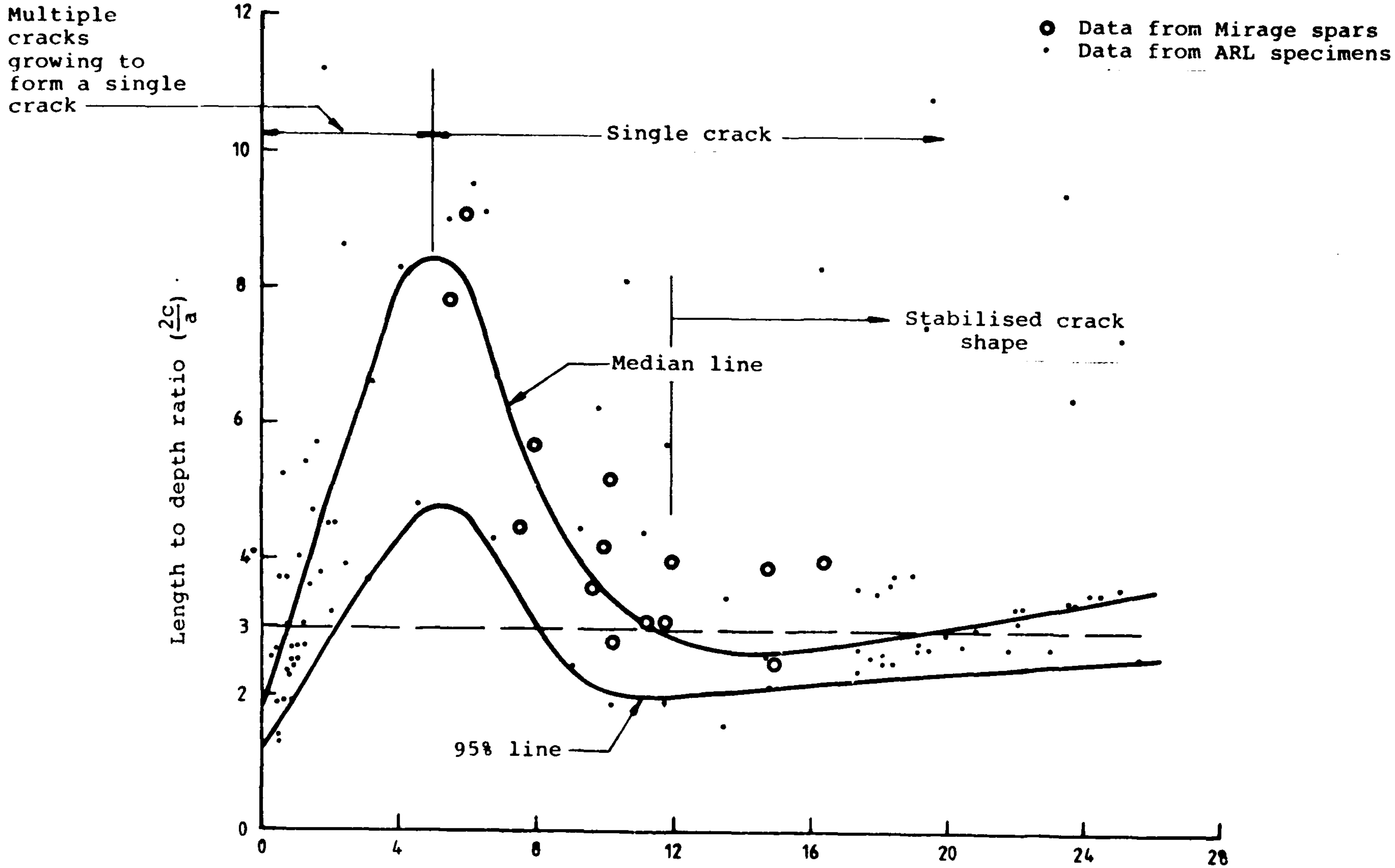


FIG. 7 CRACK LENGTH TO DEPTH RATIO
(From Ref. 23)

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